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Plant Community and Soil Properties Regulate Space-Scale Dependence of Species Diversity under Grazing Exclusion and Rest Grazing in the Qilian Mountains of China

Lixiang Liu 1,2, Yongwei Han 1,2, Weiwei Liu 1,2,* and Yuemin Liu 3

1 State Key Laboratory of Environmental Criteria and Risk Assessment, Chinese Research Academy of Environmental Sciences, Beijing 100012, China; liulixiang1982@126.com (L.L.); hanyw@craes.org.cn (Y.H.)
2 Institute of Ecology, Chinese Research Academy of Environmental Sciences, Beijing 100012, China
3 College of Natural Resources and Environment, Northwest A&F University, Yangling 712100, China; 1514387767@nwafu.edu.cn
* Correspondence: liuww@craes.org.cn

Abstract: Grazing exclusion (GE) and rest grazing (RG) are important management systems for the restoration of degraded grassland ecosystems. In order to evaluate the effects and mechanisms of different grazing management systems on the scale dependency of species diversity, plant community indices and soil variables were determined in 32 plots in the Qilian Mountains in Gansu Province. The results show that diversity effects and their regulating mechanisms had space-scale dependence under different grazing management systems. The species richness and species diversity indices of RG grassland were significantly higher than those of GE at the regional scale. Species richness for RG and GE plots was 128 and 98, respectively, and the Shannon–Wiener and Simpson indices for RG and GE plots were 2.26 and 2.16, and 0.85 and 0.83, respectively. Additionally, three grazing management systems had a significant effect on species richness in mountain meadows, but different management systems had significantly different effects on species diversity indices in mountain meadows and temperate steppes. Meanwhile, soil variables only influenced species diversity at the regional scale. Most of the plant and soil variables at each scale had positive effects on species diversity. However, a negative correlation was seen between biodiversity and species coverage, mean plant height, soil porosity (SP) and bulk density (BD) under the two contrasting grazing management systems. In conclusion, choosing RG at the regional scale and selecting grazing management systems according to different grassland types at the local scale can help to restore degraded grassland vegetation.

Keywords: grazing management; regional scale; local scale; diversity effect; alpine grasslands; mountain meadows; temperate steppe

1. Introduction

Alpine grasslands cover over 60% of the Qinghai–Tibetan Plateau and 25% of Chinese total territorial lands [1–3], and they are an important location for livestock production. Owing to the vulnerability of the ecosystem and anthropological activity, the alpine grasslands on the Qinghai–Tibetan Plateau have been severely degraded and undergone dynamic changes in ecosystem function due to long-term grazing at multiple scales in recent decades, including changes in plant diversity, vegetation biomass, soil properties, soil conservation and water conservation [3,4]. Recently, a series of grazing management strategies were launched to protect and make sustainable use of grasslands in China [5–7], which include the “Grazing for Green Program”, “Grassland Ecological Protection Program” and “Return Grazing Land to Grassland Program” [8–11]. Numerous studies have considered different grazing management practices, mainly including GE, rotational grazing and RG (compared to no grazing), to restore degraded grasslands [12,13], but, to date, there have been few comparisons between grazing regimes, especially in terms of biodiversity and natural
habitats [14,15]. Thus, a better understanding of the effect of grazing management practices on biodiversity and the mechanisms behind it is needed for alpine grassland restoration.

Although grazing management as mentioned above has been regarded as an effective method for the recovery of degraded alpine grassland (e.g., plant height and coverage), the effects of grazing exclusion and rest grazing on plant diversity have not been conclusively described; they are dependent on different conditions at different temporal or spatial scales [16–18]. Some studies have indicated that GE increases plant diversity, whereas others have reported a decrease or no change [19–23]. For example, Song et al. [24] reported that long-term GE reduced species diversity under four treatments in the alpine meadow ecosystem near the Haibei national field research station in China. Plant diversity at grazing exclusion sites and at grazing sites was 1.29 and 1.04 in mountain meadows, respectively, but was 1.46 and 1.72 in temperate typical steppes, respectively [16]. Plant diversity was higher in GE sites than in the grazing sites in rangelands in Saral [25]. McDonald et al. [26] found that RG had different effects on plant diversity when compared to grazed areas or ungrazed areas. However, to our knowledge, most of these studies consisted of site-specific controlled grazing management experiments based on grazed–ungrazed contrasts (i.e., grazing versus enclosure or rest grazing) [17,27], indicating that the effects of the grazing regimes on plant diversity were spatial-scale-dependent, but it is important to understand the effects of grazing regimes on plant diversity at a larger scale (dependence) from a management strategy perspective.

Experiments on the mechanisms and effects of grazing management types on plant diversity have yielded general results but no conclusions related to scale dependency [18,27,28]. Previous studies have shown that the effects of the grazing regime on species diversity depend largely on local variables (site-specific) and regional variables (vegetation types and the duration of grazing exclusion) [17,29,30]. Previous studies have reported that GE has varying effects on plant diversity in different grassland types [16,31]. For example, Schultz et al. [32] found that the effects of GE on plant species richness and phytomass accumulation varied across a regional productivity gradient. Species richness is scale-dependent [33–35], especially the species–area relationship [36]. Li et al. [37] reported that moderate grazing was a possible reason for the use of RG as a sustainable grazing management strategy. Most of these studies were restricted to specific vegetation types or to a single scale, and very few studies have attempted to derive general conclusions, especially at different spatial scales, from a grazing management strategy perspective [27,38].

The Qilian Mountains are an important ecological security barrier in Northwest China, where most grasslands have been degraded because of climate change, over-grazing and inadequate integrated management in the past [39]. In the present study, an investigation was conducted to evaluate the response of degraded grassland ecosystems to grazing management to address the following questions: (1) How has grazing management affected the vegetation and soil characteristics? (2) Are the effects of different grazing management systems (GE and RG) on grassland species diversity scale-dependent? (3) What are the regulatory mechanisms of grassland species diversity under different grazing management strategies (GE and RG) at different spatial scales?

2. Materials and Methods

2.1. Study Sites

The study was conducted in the Qilian Mountains, in the Tianshu and Yongchang Counties of Gansu Province (102°01′–103°40′ E and 36°30′–37°35′ N), which is located in the arid and semi-arid desert region of Northwest China, at the intersection of the Qinghai–Tibet Plateau, Inner Mongolia Plateau and Loess Plateau, with elevation ranging from 2040 m to 4874 m above sea level (asl) [2]. The climate in the northern and southern areas is temperate continental semi-arid and continental highland monsoon, respectively. They are separated by the Wushao Mountains, with total yearly solar radiation of 130 kcal/cm², a maximum sunshine duration of 4434 h and a frost-free season of approximately 130 days. The annual average temperature and precipitation range from 0.2 °C to 4 °C and from
260 mm to 500 mm, respectively [2]. The annual evaporation ranges from 1200 mm to 1700 mm [2].

At the study site, Tianzhu County and Yongchang County have cumulatively established mesh fencing with a total of 360,000 hm$^2$ and 200,000 hm$^2$ since 2018, respectively.

2.2. Experimental Design

The experiment was established in 2019 to study the effects of grazing management on plant diversity (Figure 1). In this study, in a randomized block design, five grassland management types were included to form 4 experimental sites, which were divided into 32 plots (33.3 m $\times$ 33.3 m) with 96 subplots (Table 1). Experimental sites were included in Songshan Township with temperate steppes, in Zhuaxi Xiulong Township with alpine meadows and mountain meadows, in Haxi Township with alpine meadows and mountain meadows and in Xinchengzi Township with mountain meadows. Five grazing management types were selected, including three GE types and two RG types. GE types included 10-month, 4-year and a long-term (more than 20 years) grazing exclusion. The long-term grazing exclusion site was selected within the Haxi Nature Reserve. RG types included winter grazing (in the non-growing seasons) and summer grazing (in the growing seasons) (the duration of rest grazing was not specified).

![Figure 1. Sampling plots.](image)

<table>
<thead>
<tr>
<th>Grassland Type</th>
<th>Number of Plots</th>
<th>Returning Grazing Lands to Grasslands</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountain meadow</td>
<td>5</td>
<td>Grazing exclusion</td>
<td>&gt;20 years</td>
</tr>
<tr>
<td>Mountain meadow</td>
<td>6</td>
<td>Grazing in the non-growing seasons</td>
<td>unknown</td>
</tr>
<tr>
<td>Mountain meadow</td>
<td>5</td>
<td>Grazing exclusion</td>
<td>10 months</td>
</tr>
<tr>
<td>Alpine meadow</td>
<td>1</td>
<td>Grazing exclusion</td>
<td>&gt;20 years</td>
</tr>
<tr>
<td>Alpine meadow</td>
<td>5</td>
<td>Grazing in the growing seasons</td>
<td>unknown</td>
</tr>
<tr>
<td>Temperate grassland</td>
<td>5</td>
<td>Grazing exclusion</td>
<td>4 years</td>
</tr>
<tr>
<td>Temperate grassland</td>
<td>5</td>
<td>Grazing in the non-growing seasons</td>
<td>unknown</td>
</tr>
</tbody>
</table>
2.3. Sampling and Measurements

2.3.1. Vegetation Sampling and Measurements

Plant communities were surveyed within each plot using three 1 m × 1 m quadrats to measure plant species abundance and biomass (including aboveground biomass and belowground biomass). In each quadrat, plant species were identified [40,41] (Table S1), and the abundance of each species (clumps) was counted [42]. The height of each plant species in the subplot was investigated using a metal rod and a tape measure. We estimated the plant community cover and the relative cover of each species. Aboveground biomass (AGB) was determined by clipping all living plants to ground level, after which they were oven-dried at 65 °C for 48 h to a constant weight and then weighed. Belowground biomass was calculated by the soil core method as described below.

The species richness index (S), evenness index (Pielou index (E)) and diversity indices (Shannon–Wiener index (H') and Simpson index (D)) were calculated to reflect species diversity using the method described in Ma et al. [43].

\[
\text{Richness index (S)} = N \quad (1)
\]

\[
\text{Shannon-Wiener index (H')} = -\sum (Pi \times \ln Pi) \quad (2)
\]

\[
\text{Simpson diversity index (D)} = 1 - \sum Pi^2 \quad (3)
\]

\[
\text{Pielou index (E)} = \frac{H'}{\ln S} \quad (4)
\]

where \(N\) is the total number of species, \(S\) is the number of species in the sample plot and \(Pi\) is the ratio of the number of individuals of species \(i\) to the total number of individuals.

2.3.2. Soil Sampling and Measurements

We collected soil samples (in 0–10 cm, 10–20 cm and 20–30 cm) using a soil drill and soil cores (5 cm diameter × 5 cm depth) to analyze soil physical–chemical properties. Soil cores were used to measure soil BD, SP, field capacity (FC) and belowground biomass. Other physical–chemical variables were calculated in a soil sampler. All the samples were stored in ice coolers and transported to a laboratory for analysis within 1 week.

In each plot, three cores at 0–10 cm, 10–20 cm and 20–30 cm (5 cm diameter × 5 cm depth) were set up for a total of 9 soil cores in each plot. Soil cores were kept 10 cm belowground to obtain the most roots, since most species have a shallow root system in the Qilian Mountains grassland. A soil column was immersed in water for 24 h and then carefully washed to obtain the roots of co-occurring species. Water content and BD were calculated by using the oven-dried weight of the soil sample at 105 °C. SP was calculated by BD and specific gravity using the formula \(\text{SP} (%) = \left(1 - \frac{\text{BD}}{\text{specific gravity}}\right) \times 100\). Soil texture was analyzed by laser diffraction (Mastersizer 2000, Malvern company, UK) [44] and divided into three particle sizes: <0.002 mm clay content, 0.002–0.02 mm silt content and 0.02–2 mm sand content. At the time of pot filling, the moisture content of the soil at field capacity was gravimetrically determined by watering the pots filled with soil to flooding and the pots were left overnight. The pots were 30 cm × 20 cm × 10 cm (length × width × height). The air dry weight of the soil samples and the wet weight after drainage overnight were recorded [45].

The soil organic carbon (SOC) content was determined via potassium dichromate–ferric sulfate titration. Soil total nitrogen content (TN) was determined using the semi-micro Kjeldahl method, and soil total phosphorus (TP) content was measured using the sulfuric acid–perchloric acid digestion–molybdenum antimony colorimetric method. Soil total potassium (TK) was measured using hydrofluoric acid–perchloric acid digestion and the flame photometric method. The above determination methods are included in Soil and Agricultural Chemistry Analysis [46].
2.4. Statistical Analysis

Various environmental variables, especially soil variables in different layers, were also measured at each individual plot and then averaged when we used them.

In order to analyze the effect of different grazing management types on plant diversity at the regional scale in the grassland, generalized linear mixed models (GLMM) were constructed using the lmer function in the lme4 package in R 4.2.1. The response variables, fixed variables and random variables in GLMM were species diversity indices, grazing management types and grassland types, respectively.

At the local scale, different grazing management types and grassland types were included as fixed variables in GLMM. However, their interactions were not significant, indicating that the effect of different grazing management types on the plant communities in grasslands were not dependent on the grassland type. Therefore, one-way ANOVA followed by a post hoc Tukey’s test and paired t test were used to analyze the effects of different grazing management types in the same grassland type on species diversity and plant community characteristics. There was only one grazing exclusion plot for alpine meadows, so it was not included in the comparison analysis of the mean values for the relevant indicators.

All statistical analyses were performed using the SPSS 17.0 statistical software (SPSS Inc., Chicago, IL, USA), and graphs were created using the Sigma Plot 11.0 program (Systat Software Inc., San Jose, CA, USA).

3. Results

3.1. Responses of Different Grazing Management Types on Vegetation and Soil Characteristics

For vegetation community characteristics, the two contrasting grazing management types had no significant effect on the community height, community coverage and community biomass at different scales \( (p > 0.05) \), except that the community coverage in mountain meadows under the 10-month GE was significantly smaller than those under the other two grazing management types \( (p < 0.05) \) (Table 2).

For soil characteristics, the two contrasting grazing management types significantly affected the SOC content and sand content (0.02–2 mm) at the regional scale \( (p < 0.05) \), but had different effects on soil variables for different grassland types. The two contrasting grazing management types significantly affected the TN content and BD in temperate steppes \( (p < 0.05) \) (Table 2). The SOC content of RG in mountain meadows was significantly higher than that of the other two management types \( (p < 0.01) \). The TN content in mountain meadows under the 10-month GE was significantly smaller than that under other grazing management types \( (p < 0.01) \). The TK content of GE in mountain meadows was significantly smaller than that of other grazing management types \( (p < 0.05) \). The FC and clay content (<0.002 mm) of RG in mountain meadows were significantly different from that under the 10-month GE \( (p < 0.05) \). It should be noted that the two contrasting grazing management types had no significant effects \( (p > 0.05) \) on other soil variables (Table 2).
<table>
<thead>
<tr>
<th>Index</th>
<th>Mountain Meadow</th>
<th>Alpine Meadow</th>
<th>Temperate Steppe</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grazing Exclusion</td>
<td>Rest Grazing</td>
<td>Grazing Exclusion</td>
<td>Rest Grazing</td>
</tr>
<tr>
<td>Coverage (%)</td>
<td>99.20 a</td>
<td>96.83 a</td>
<td>66.20 c</td>
<td>81.00</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>9.81 ab</td>
<td>15.58 a</td>
<td>19.89 a</td>
<td>4.57</td>
</tr>
<tr>
<td>Species richness</td>
<td>68 b</td>
<td>69 a</td>
<td>35 c</td>
<td>16</td>
</tr>
<tr>
<td>Pielou index</td>
<td>0.78 a</td>
<td>0.76 a</td>
<td>0.79 a</td>
<td>0.78</td>
</tr>
<tr>
<td>Shannon–Wiener index</td>
<td>2.63 a</td>
<td>2.41 a</td>
<td>2.09 cb</td>
<td>2.22</td>
</tr>
<tr>
<td>Simpson</td>
<td>0.89 a</td>
<td>0.87 a</td>
<td>0.84 c</td>
<td>0.86</td>
</tr>
<tr>
<td>Aboveground biomass (g/m²)</td>
<td>377.08 a</td>
<td>355.42 a</td>
<td>350.77 a</td>
<td>185.36</td>
</tr>
<tr>
<td>Belowground biomass (g/m²)</td>
<td>1898.60 a</td>
<td>1407.60 a</td>
<td>1253.40</td>
<td>405.27 a</td>
</tr>
<tr>
<td>Soil organic carbon (mg/g)</td>
<td>39.32 c</td>
<td>69.48 a</td>
<td>25.27 c</td>
<td>48.52</td>
</tr>
<tr>
<td>Soil nitrogen (mg/g)</td>
<td>5.58 a</td>
<td>6.82 a</td>
<td>2.79 c</td>
<td>4.97</td>
</tr>
<tr>
<td>Soil total phosphorus (mg/g)</td>
<td>0.61 a</td>
<td>0.72 a</td>
<td>0.73 a</td>
<td>0.62</td>
</tr>
<tr>
<td>Soil total potassium (mg/g)</td>
<td>3.90 b</td>
<td>5.75 a</td>
<td>5.75 ac</td>
<td>4.11</td>
</tr>
<tr>
<td>Soil bulk density (g/cm³)</td>
<td>0.68 a</td>
<td>0.72 a</td>
<td>0.89 a</td>
<td>0.52</td>
</tr>
<tr>
<td>Soil porosity (%)</td>
<td>46.57 a</td>
<td>54.54 a</td>
<td>40.17 a</td>
<td>27.69</td>
</tr>
<tr>
<td>Field capacity (%)</td>
<td>58.79 ab</td>
<td>74.95 a</td>
<td>40.63 bc</td>
<td>35.39</td>
</tr>
<tr>
<td>&lt;0.002 mm clay content (%)</td>
<td>7.59 ab</td>
<td>8.63 b</td>
<td>9.93 a</td>
<td>7.67</td>
</tr>
<tr>
<td>0.002–0.02 mm silt content (%)</td>
<td>64.77 a</td>
<td>79.78 a</td>
<td>81.42 a</td>
<td>74.53</td>
</tr>
<tr>
<td>0.02–2 mm sand content (%)</td>
<td>10.98 a</td>
<td>11.59 a</td>
<td>8.64 a</td>
<td>17.80</td>
</tr>
</tbody>
</table>

Note: Belowground biomass could not be collected in alpine meadows under GE and in mountain meadows under the 10-month grazing exclusion. The same letters indicate \( p > 0.05 \), adjacent letters without the same letter indicate \( p < 0.05 \) and letters that are neither the same nor adjacent indicate \( p < 0.01 \).
3.2. Effects of Different Grazing Management Types on Species Diversity

3.2.1. Species Richness

There were significant differences for species richness between GE and RG at the regional scale (df = 28.82, t = 2.02, p = 0.05, R² = 0.84), whereas the different grazing management types in mountain meadows had only significant effects on species richness (df = 2, F = 34.03, p = 0). Specifically, the species richness of GE in grasslands was significantly smaller than that of RG. The species richness of RG in grasslands was approximately 30.30% higher than that of GE. In addition, species richness in mountain meadows was significantly higher (p < 0.05) under long-term GE than that under winter grazing (RG) and 10-month GE, followed by winter grazing, long-term GE and 10-month GE in decreasing order (Table 2).

3.2.2. Diversity Indices

There were significant differences in species diversity between GE and RG at different scales (p < 0.05). The Shannon–Wiener index of GE was significantly smaller (df = 25.74, t = 2.22, p = 0.036, R² = 0.71) than that of RG (Figure 2). The Simpson index of GE was significantly lower (df = 27.65, t = 2.36, p = 0.026, R² = 0.69) than that of RG (Figure 2). Additionally, grazing management in mountain meadows had significant effects on diversity indices (df = 2, F = 6.35, p = 0.012). The Shannon–Wiener index and Simpson index in mountain meadows under the 10-month GE were both significantly smaller than those under the other two grazing management types (p < 0.05). For temperate steppes, the Shannon–Wiener index and Simpson index of GE were both significantly lower than those of RG (Shannon–Wiener index F = 17.25, p = 0.003; Simpson index F = 8.32, p = 0.02) (Table 2).

![Figure 2](image-url). Comparison of Shannon–Wiener index and Simpson index based on generalized mixed model in grassland in Qilian Mountains. Note: The different lowercase letters are significantly different as determined by generalized linear mixed models on a regional scale (p < 0.05).

3.2.3. Evenness

Grazing management did not significantly affect the evenness in grasslands at different scales (p > 0.05) (Table 2).
3.3. Regulatory Mechanisms of Different Grazing Management Types on Species Diversity

Our results showed that species diversity indices were mainly regulated by community coverage, above- and belowground biomass, water retention and nutrient variables in soil at different scales.

3.3.1. Regulatory Mechanisms of Community and Soil Characteristics on Species Richness

Specifically, a highly significant positive linear regression relationship of RG was found between community coverage and species richness ($R^2 = 0.65$, $p < 0.01$) at the regional scale, even between community coverage and belowground biomass under GE ($R^2 = 0.62$ and $0.64$, respectively, $p < 0.01$). It should be noted that neither the belowground biomass of RG nor the aboveground biomass of GE was significantly associated with species richness ($p = 0.069$ and $0.087$, respectively) (Figures 3 and 4). In addition, species richness increased linearly with the SOC, TN, FC and C/K of RG ($R^2 = 0.46$, $0.54$, $0.32$ and $0.55$, respectively; $p = 0.001$, $0.003$, $0.027$ and $0.002$, respectively) and increased with the TN, C/K and N/P of GE ($R^2 = 0.63$, $0.58$ and $0.66$, respectively; $p = 0$, $0.001$ and $0$, respectively), but decreased with the TK and BD of GE in the regression equations ($R^2 = 0.31$ and $0.25$; $p = 0.026$ and $0.047$, respectively) (Figures 5 and 6).

Figure 3. Relationship between community characteristics and species diversity in GE of regional grassland.
Figure 4. Relationship between community characteristics and species diversity in RG of regional grassland.

Figure 5. Relationships between species diversity and soil variables in GE of grassland.
Figure 6. Relationships between species diversity and soil variables in RG of grassland.

At the local scale, different community characteristics influenced species richness in different grassland types under different grazing management types. There was a highly significant positive regression relationship between community coverage and species richness in mountain meadows under GE ($R^2 = 0.71, p = 0.0020$), but a significant negative regression relationship between species coverage and species richness in temperate steppes under RG ($R^2 = 0.86, p = 0.023$). Additionally, species richness was slightly positively correlated with the aboveground biomass of RG in temperate steppes ($p = 0.089$) and in alpine meadows ($p = 0.078$), but negatively correlated with community height and species coverage ($0.05 < p < 0.1$) (Figures 7–9). It should be noted there were no relationships between species richness and other community characteristics in grasslands under grazing management ($p > 0.10$).
Figure 7. Relationships between community characteristics and species diversity in RG of alpine meadows.

Figure 8. Relationships between community characteristics and species diversity in GE of mountain meadows.

Figure 9. Relationships between species coverage and species diversity in RG of mountain meadows and temperate steppes.

3.3.2. Regulatory Mechanisms on Species Diversity by Community and Soil Characteristics

At the regional scale, the Shannon–Weiner index of RG was positively associated with community coverage ($R^2 = 0.40, p = 0.009$), but the Simpson index of RG was only...
slightly related to community coverage under RG \((p = 0.069)\) in the regression analyses. Specifically, the Shannon–Weiner index and Simpson index of GE were positively related to both community coverage \((R^2 = 0.54 \text{ and } 0.42; \ p = 0.0010 \text{ and } 0.0070)\) and biomass (aboveground and belowground, \(p < 0.050)\). At the same time, the species diversity indices increased with the SOC content, TP content, SP, FC, C/N and C/K of RG \((R^2 = 0.54, 0.47, 0.71, 0.56, 0.38 \text{ and } 0.34; \ p = 0.002, 0.005, 0, 0.001, 0.018 \text{ and } 0.023 \text{ for Shannon–Wiener index, respectively}; R^2 = 0.40, 0.40, 0.65, 0.48 \text{ and } 0.43; \ p = 0.011, 0.011, 0, 0.004, 0.011, \text{ no data for CK for Simpson index, respectively})\). Species diversity increased with the SOC content, TN content, C/P, C/K and N/P of GE \((p = 0.004, 0, 0.001, 0 \text{ and } 0.013 \text{ for Shannon–Wiener index, respectively}; \ p = 0.004, 0.002, 0.001, 0.001, 0.044 \text{ for Simpson index, respectively})\), but decreased with the BD of GE \((p = 0.006 \text{ and } 0.006 \text{ for Shannon–Wiener index and Simpson index, respectively})\).

3.3.3. Regulatory Mechanisms on Evenness by Community Characteristics

At the local scale, different community characteristics influenced species diversity indices in different grassland types under different grazing management types. There was a significant positive and linear regression relationship of RG in alpine meadows between the aboveground biomass and both the Shannon–Weiner index and Simpson index \((R^2 = 0.89 \text{ and } 0.85; \ p = 0.016 \text{ and } 0.025)\). Specifically, the Shannon–Wiener index and Simpson index in mountain meadows were strongly associated with the species coverage of RG and the community coverage of GE \((R^2 = 0.81 \text{ and } 0.87; \ p = 0.015 \text{ and } 0.0070)\). In addition, the Shannon–Wiener index was also significantly related to the community height of GE in mountain meadows \((R^2 = 0.40; \ p = 0.048)\). However, species diversity was only slightly positively related to community coverage of RG in mountain meadows \((p = 0.092)\), community height in mountain meadows of GE \((p = 0.056)\) and community height and species coverage of GE in temperate steppes \((0.05 < p < 0.10)\). There were no relationships between species diversity and community characteristics in grasslands under different grazing management types \((p > 0.10)\) (Figures 7–9).

4. Discussion

4.1. Significant Effects of Different Grazing Management Types on Species Diversity

Ecologists have not yet reached a consensus regarding the effects of different grazing management types on species diversity. Controversial issues include increasing plant diversity \([19,20]\), decreasing plant diversity \([22]\) or no significant changes in plant diversity \([21]\). In the present study, there were significant effects of two contrasting grazing management types (RG and GE) on species richness and diversity indices in grasslands at different scales, but no effect on species evenness. Meanwhile, long-term grazing exclusion and RG both increased the amounts of taller plants in grasslands in our study, which mainly included *Ranunculus tanguticus*, *Cirsium souliei*, *Poa annua* and *Polygonum viviparum* under long-term
grazing exclusion, and *Elymus nutans*, *Oxytropis ochrocephala*, *Polygonum viviparum*, *Poa annua* and *Medicago archiducis-nicolai* under rest grazing. These resulted in decreasing space for short plants to grow. Species richness and species diversity indices in grassland were higher under RG than under GE at the regional scale, which was consistent with previous studies in the Qilian Mountains [47] and Hulunbeir grasslands [48]. At the same time, our results showed that the species richness and species diversity indices of RG only in mountain meadows and temperate steppes under rest grazing were greater than those under short-term grazing exclusion, which was consistent with previous studies [49–52]. The reason for this result may be that moderate grazing is beneficial to increase species diversity in degraded grasslands [53,54]. Additionally, RG was more suitable for nutritional growth, seed maturation in edible forage, the renewal and utilization of grassland resources and the sustainable development of grasslands, supporting the “intermediate disturbance” hypothesis [9,52]. Moreover, RG in grasslands caused the community characteristics to remain stable, particularly regarding the growth attributes of grasslands, without harming them. In particular, RG is usually seasonal, which reduces intense species competition. In contrast, past studies reported that GE had negative impacts on species diversity and species evenness [55,56]. Generally speaking, GE allows the pasture to rest, regenerate and regrow, which results in competition among species for limited resources such as light and nutrients. As reported in previous studies, appropriate grazing disturbances can increase the species diversity in grasslands, while GE may lead to a decrease in species diversity [57,58]. However, GE may make plant community structures uniform and lead to a decrease in the community anti-interference ability. Additionally, our findings regarding RG are in contrast to some past findings [58], such as those of Bai et al. [50]. This may be due to the differences in the season selected for rest grazing [13], the grazing intensity influencing grassland vegetation [51] and other environmental conditions [59].

It should be noted that there were no significant differences in species richness and species diversity indices between long-term grazing exclusion and RG in mountain meadows at the local scale. This is consistent with the findings of [53,60] in terms of species richness. As mentioned earlier, this could be because the grazing period of RG in mountain meadows was approximately 9 months under only winter grazing management, which caused a high grazing intensity. A high grazing intensity would offset the positive benefits from rest grazing, resulting in the species diversity indices being consistent with the long-term grazing exclusion results. Therefore, the differences in species diversity between the two contrasting grazing management types were not significant after a certain period of GE or RG.

### 4.2. Regulatory Mechanisms of Scale Effect on Species Diversity by Different Grazing Management Types

Past studies found that the decline in species diversity in grasslands is associated with factors such as nutrient overloading and grazing [61,62]. In an era of rapid species extinction, exploring the regulatory mechanisms of species diversity under different grazing management types is urgently required. Our study showed that species diversity under different grazing management types at multiple scales had different regulatory mechanisms in the grasslands of the Qilian Mountains. Positive and negative interactions between species diversity and their regulating factors, which represent facilitation and competition, occurred simultaneously in our study. In particular, negative diversity effects suggested that resource competition is more prevalent than niche complementarity at a small scale. However, at a large scale, competition pressure may be reduced and increased facilitation may occur, thus generating positive diversity effects.

Meanwhile, soil variables only affected species diversity at the regional scale under the two contrasting grazing management types. This could be attributed to the fact that the heterogeneous distribution of soil conditions at a broad scale may cause community patches and thus influence species diversity, but the nonsignificant effects of soil variables at a local scale may have been due to the homogeneous soil conditions in our sampling sites. In terms
of soil physics, the negative diversity effect of BD under GE may have emerged because GE increased species diversity, resulting in increasing soil water storage and consequently low BD [63,64]. For example, earlier studies reported that grazing increased BD, resulting in reduced SP [63–65], but RG maintained the BD in alpine meadows [8]. It should be noted that the positive diversity effect regarding FC and SP under RG occurred as mentioned above, which was in accordance with other findings reported [63,66,67]. Likewise, from a soil nutrients perspective, the factors regulating species diversity under the two contrasting management types were the SOC content and TN content, while the regulating factors under RG and GE were the TP content and TK content, respectively. The positive diversity effect regarding soil nutrients under the two contrasting grazing management types was similar to that in other studies [68] and could be due to the fact that high levels of soil nutrients support plant growth and further promote species diversity under grazing management, as well as the heterogeneous distribution of soil nutrients, as mentioned above. The SOC content and TN content play vital roles in plant growth, therefore increasing species diversity [17,63]. Dong et al. [18] stated that RG notably increased the TP content owing to excretion by herbivores in the form of dung and urine [63,66]. Moreover, our results showed a negative richness effect, which may have been due to the fact that herbivores did not excrete the compounds via dung and urine under GE [66]. In line with our results, past findings found higher TK content in grazed areas as compared to protected areas, indicating that livestock trampling and droppings can accumulate potassium [69,70].

Regarding the soil stoichiometric ratios, the factor regulating species diversity under the two contrasting management types was C/K, while the regulating factors were C/N for RG and N/P and C/P for GE, respectively. Firstly, some studies reported that C/K had a positive correlation with SOC content [13], with both affecting species diversity. On the other hand, C/N under RG was positively correlated with species diversity. A probable explanation for this is the accumulation of plant litter, which alleviated the species diversity and promoted the decomposition rate, consequently causing lower C/N [13,52]. It is widely acknowledged that soil C/N reflects the decomposition rate of soil organic matter and a lower C/N ratio is associated with a faster decomposition rate. Compared to RG, GE had lower mineralization and species diversity because of the lower decomposition rate of large litter, thereby resulting in lower C/P and N/P [66].

With respect to the plant community, the vegetation community characteristics influenced species diversity at each scale with different indicators. Only at the small scale, the species diversity indices were negatively associated with the mean plant height for GE and species coverage for RG in mountain meadows. The species coverage also negatively regulated the Pielou index for RG in mountain meadows, but was negatively correlated with species richness under RG in temperate steppes in our study. Conversely, aboveground biomass was positively correlated with species diversity and evenness (Pielou index) in alpine meadows under RG. One possible reason for our results is that a small scale can lead to light competition among species, thereby affecting plant diversity variations, whereas species coverage, aboveground biomass and plant height are important indicators of light competition changes [61,71,72]. It is interesting to note that, at the local scale, species diversity had different controlling factors according to different grassland types, which was in line with other findings reported [17,73,74]. It is widely known that alpine meadows, mountain meadows and temperate steppes are the three grassland types that occur along the altitude gradient, thus leading to a discrepancy in soil water content. Alpine meadows had higher productivity and soil moisture compared to other grassland types [17]. Alternatively, mountain meadows and temperate steppes were much sparser than alpine meadows in grass species due to limited nutrients and soil moisture [73,74]. On the one hand, moderate grazing may promote litter removal and increase species diversity, resulting in increasing grazing tolerance in most species [61,62], leading to a decreasing species occupation area (coverage) owing to herbivores eating and trampling under rest grazing, not only in mountain meadows but in temperate steppes [62]. In addition, regarding the positive relationships between aboveground biomass and diversity indices and evenness
in alpine meadows, the stems and leaves of plants had priority over roots for growth under limited light, thereby increasing the community coverage and aboveground biomass under RG according to optimal allocation theory [61,62,75]. Short-term grazing under RG decreased the evenness due to reduced palatable plants such as gramineous species, sedge species and leguminous species, leading to low aboveground biomass due to the palatable plants with large amounts of shoots and leaves in alpine meadows [74,75]. On the other hand, GE leads to taller plants, causing increased resource competition among species and resulting in a high mean plant height, thus leading to decreasing species diversity compared to RG [52,76].

At the regional scale, species diversity indices and richness were positively associated with community coverage and belowground biomass (slight correlation) under RG. In line with other studies, RG increased community coverage and resulted in a positive correlation with species diversity, as in previous studies reported at a broad scale [49,77,78]. Herbivores’ consumption of taller plants facilitated the growth and assembly of smaller plants during short-term grazing periods, which increased the available light for smaller plants and increased the species coverage as discussed above, thus increasing the community coverage [34,59]. Subsequently, moderate grazing under RG promoted root biomass allocation [18]. For GE, species diversity indices were positively associated with community coverage and above- and belowground biomass, which was consistent with other studies [79,80]. This may be because GE alleviated the pressure of long-term grazing on the grassland ecosystems, leading to increasing species diversity and productivity [59,81]. Moreover, alpine meadow plants are relatively low in height after grazing; therefore, GE promoted the growth of taller plants and increased the community coverage and aboveground biomass, as discussed above for RG [74,75]. Meanwhile, GE promoted the reproduction and regeneration of suppressed species (such as gramineous species) due to the selective grazing behavior of livestock under grazing, and then increased the species richness [52]. The eating and soil trampling of livestock were eliminated in grasslands under GE, resulting in increased belowground biomass accumulation [82]. Past studies stated that plants reduced the proportion of AGB and allocated large amounts of biomass to BGB so as to germinate and resist grazing pressures as an adaptive strategy in alpine grasslands [83,84]. Thus, the aboveground biomass may be mainly derived from increasing palatable and taller plants in GE. In fact, the relative proportion of gramineous families in GE in our study was larger than that in RG. Thus, there was no relationship between species richness and aboveground biomass.

5. Conclusions

This study highlights the effect of rest grazing and grazing exclusion on plant composition, diversity and soil characteristics in the grasslands of the Qilian mountains. Our findings suggest that the community structure characteristics, species diversity indices and soil nutrition variables under rest grazing were relatively higher than under grazing exclusion. However, the Pielou index, biomass, soil bulk density and mean plant height were more affected under grazing exclusion management. The application of each of the strategies depends on the status of the degraded rangeland. Our analysis indicates also that grazing-induced changes in species diversity indices, excluding evenness, and their regulating factors are scale-dependent. Although different community and soil variables regulated species diversity at each scale, our results indicated that the temperature and soil moisture behind these variables regulated the species diversity to a certain extent under the different grazing management types. The space-scale dependence of environmental controls on species diversity has important implications in restoring and managing degraded grasslands. We recommended the improvement of the grazing management system in arid steppes to prevent further land degradation due to biodiversity loss and large-scale biotic homogenization. The implementation of “short-term grazing exclusion” in many sites at the same time and the application of seasonal grazing in the surrounding areas could enhance the ecological value of protected steppes.
Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture13101966/s1, Table S1: The list of species in the study.

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